United States
Environmental Protection
Agency

SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION

Demonstration Bulletin

Steam Enhanced Remediation

SteamTech Environmental Services, Inc.

Technology Description: Steam Enhanced Remediation (SER) is a process in which steam is injected into the subsurface and volatile and semivolatile contaminants are collected in the vapor phase, in the aqueous phase, and possibly as a nonaqueous phase liquid (NAPL). The general approach employed is to surround the contaminated zone with steam injection wells to displace NAPLs and groundwater to centrally located extraction wells. Residual contaminants are vaporized when the heat front reaches them and collected by vacuum extraction. Steam migration is monitored using Electrical Resistance Tomography (ERT) and thermocouples.

SteamTech Environmental Services, Inc. has successfully applied this technology for the recovery of contaminants from soils and aquifers, and at a fractured granite site at Edwards Air Force Base, California. The demonstration at the former Loring Air Force Base Quarry site was the first time that the steam injection technology was used at a contaminated site composed entirely of fractured limestone.

Waste Applicability: Volatile and semivolatile organic compounds (VOCs), including chlorinated solvents, fuels, and creosote, have been successfully recovered from field sites using steam injection. The steam injection process is equally effective above and below the water table. It has been used in heterogeneous soils comprised of layered soils with widely contrasting permeabilities. Steam injection at sites which have a component of fractured bedrock indicate that the process may be applicable to fractured rock. This demonstration further tests the applicability of the process in fractured limestone.

Evaluation Approach: The Maine Department of Environmental Protection and U.S. EPA evaluated the SER process at the former Loring AFB Quarry site in Limestone, Maine. The SER process was evaluated in fractured bedrock to determine its ability to enhance the recovery of VOC, gasoline range organic (GRO), and diesel range organic (DRO) NAPLs from sparsely fractured limestone. The evaluation was initiated by characterizing the fracture system and the contaminant distribution through rock cores, conventional borehole geophysics, and rock chip samples that were extracted in methanol and analyzed by EPA Method 8260. The transmissivity of the fractured rock system was determined in 10 foot intervals by using packers to isolate the intervals. Interconnectivity testing was used to determine the major interconnections between boreholes. Based on this characterization information, an injection, extraction and monitoring system was designed which included injection into three boreholes in the eastern part of the site. Extraction of groundwater and vapors was conducted from 10 boreholes in the central and western portions of the site. Daily samples of the effluent water and vapors were collected to determine the mass of contaminants recovered. Pre- and post- treatment groundwater and rock chip samples will be used to evaluate contaminant reductions. Three deep wells, two of which were angled to go under the treatment zone, will be used to evaluate whether contaminants were mobilized downward during the demonstration.

Because of the low injection rates and the fact that some extraction boreholes were not recovering a significant amount of contaminants, some of the extraction wells were converted to injection wells after about 30 days of injection. Injection continued for a total of 83 days, with extraction throughout that period and continuing for one week after injection was halted.

Preliminary Results: Figure 1 shows that initially the effluent water concentrations decreased with time, as is common in groundwater pump-and-treat systems. However, after approximately 3 weeks of steam injection, the concentrations started to noticeably increase, eventually reaching concentrations that were more than an order of magnitude greater than initial concentrations. Concentrations remained high at the end of the demonstration. The final sample had a DRO concentration of 17,800 µg/l (not shown on the graph).

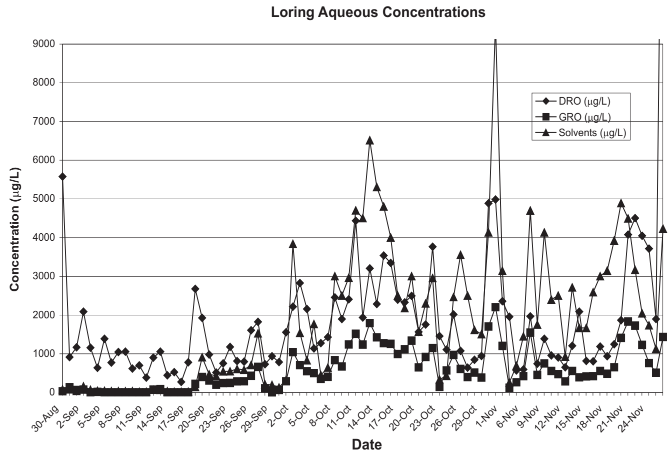

Figure 1.

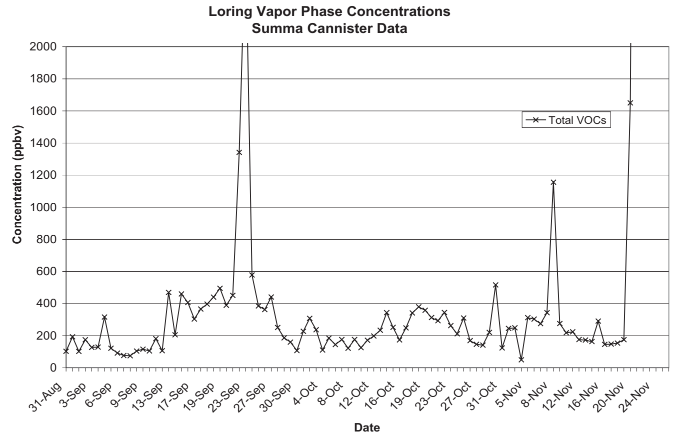

Figure 2.

Figure 2 shows notable increases in vapor phase concentrations after 3 weeks and when pressures in the subsurface were reduced by halting steam injection. Subsurface temperature and ERT monitoring indicated that steam and hot water condensate followed narrow paths in the limestone, and only a small fraction of the rock was heated to steam temperature.

Even though this demonstration was not taken to completion due to funding limitations, the observed steam flow and removal mechanisms in this highly complex system suggest that SER can be effective for increasing the mass removal rate compared to more traditional methods.

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